US006640015B1

(12) **United States Patent**
Lafruit et al.

(10) **Patent No.: US 6,640,015 B1**
(45) **Date of Patent: Oct. 28, 2003**

(54) **METHOD AND SYSTEM FOR MULTI-LEVEL ITERATIVE FILTERING OF MULTI-DIMENSIONAL DATA STRUCTURES**

(75) Inventors: **Gauthier Lafruit**, St.-Lambrechts-Woluwe (BE); **Lode Nachtergaele**, Leuven (BE)

(73) Assignee: **Interuniversitair Micro-Elektronica Centrum (IMEC VZW)**, Leuven (BE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/243,002**

(22) Filed: **Feb. 2, 1999**

Related U.S. Application Data

(60) Provisional application No. 60/088,196, filed on Jun. 5, 1998.

(51) **Int. Cl.**[7] **G06T 5/00**; G06F 17/14

(52) **U.S. Cl.** **382/260**; 382/240; 708/308; 708/401

(58) **Field of Search** 382/260, 240, 382/304, 276; 375/240.19, 240.29; 708/308, 401

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,709,394 A		11/1987	Bessler et al.	382/240
5,048,111 A	*	9/1991	Jones et al.	382/240
5,561,617 A	*	10/1996	van der Wal	708/308

FOREIGN PATENT DOCUMENTS

EP	0 574 969 A2	5/1993	G06F/15/68
EP	0 444 874 A2	2/1997	G06F/15/68

OTHER PUBLICATIONS

"The Lifting Scheme: A New Philosophy in Biorthogonal Wavelet Constructions" Wim Sweldens, Proc. of the SPIE Conference, vol. 2569, pp. 68–79, 1995.

"VSLI architectures for Discrete Wavelet Transforms" Keshab K. Parhi & Takao Nishitani, IEEE Transactions on VSLI Systems, vol. 1, No. 2, Jun. 1993.

"Calculation Of Minimum Number Of Registers In 2–D Discrete Wavelet Transforms Using Lapped Block Processing" Tracy C. Denk & Keshab K. Parhi, IEEE Int. Symposium on Circuit and Systems, vol. 3, pp. 77–80, May 1994.

"The Recursive Pyamid Algorithm for the Discrete Wavelet Transform" M. Vishwanath, IEEE Transations on Signal Processing, vol. 42, No. 3, pp. 673–676, Mar. 1994.

"A VLSI Architecture for Real–Time Hierarchical Encoding/Decoding of Video using the Wavelet Transform" M. Vishwanath & Chaitali Chakrabarti, Proceedings of the International Conference on Acoustics, Speech and Signal Processing, Adelaide, Australia, pp. II–401, II–404, Apr. 1994.

* cited by examiner

Primary Examiner—Scott Rogers
(74) *Attorney, Agent, or Firm*—Knobbe, Martens, Olson & Bear, LLP

(57) **ABSTRACT**

A system and method for multi-level iterative filtering of a data structure, e.g., an image, wherein elements of the data structure form the zero layer in the zero level and the data layer in each subsequent level is given by the results of one iteration. First, the method of the present system includes subdividing each level into a plurality of regions, there being data dependency between the data in one data layer in one level and the data layers in any other level of a region. Second, the method includes filtering each level by lapped-region processing. Lastly., the method includes scheduling the data processing of each level to provide substantially regional synchronization of the filtering at each level. In one embodiment, the sequence for traversing the regions is selected so that outputs from processing the regions are scheduled to occur at substantially equal time intervals. Also, in one embodiment, when the processing is stopped at the end of one region, the data dependencies in adjacent unprocessed regions are stored. The method of the present invention may be used for encoding or decoding.

40 Claims, 40 Drawing Sheets